ASSOCIATION BETWEEN PHYSICAL FITNESS AND JOB PERFORMANCE IN SOUTH AFRICAN FIRE-FIGHTERS

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ABSTRACT

Aim

Accurate correlations between a wide range of physical fitness measures and occupational demands are needed in order to identify specific fitness tests and training needs for firefighters.

Methods

Forty-eight experienced, professional firefighters (29 ± 7.24 yrs) participated in fitness and job performance testing sessions each spaced a week apart. Analysis was performed using Pearson moment correlation coefficients and multiple linear regression with alpha set at $p \leq .05$.

Results

Significant correlations ($p \leq .01$) were found between a job performance task (Revised Grinder) and the following: lean muscle mass (r = -.69), overall fitness (r = -.62), height (r = -.62), strength endurance: deadlift (r = -.54), bent-over row (r = -.51), bench press (r = -.51), shoulder press (r = -.46); maximal strength: hand grip strength (r = -.57), bench press (r = -.51), anaerobic capacity: 400m (r = .50), and aerobic capacity: multistage shuttle run (r = -.46). Multiple linear regression determined that lean muscle mass and aerobic capacity account for 82% of the variation in the job performance task.

Conclusion

It is apparent that firefighting taxes virtually all aspects of physical fitness. This data can help the exercise specialist choose appropriate tests and prescribe specific fitness programmes for firefighters. Traditional firefighter exercise programmes focusing mainly on cardiovascular fitness should be replaced with physical conditioning programmes that address all components of fitness. Cardiovascular fitness testing should include the performance of job-related tasks to improve test validity.

Keywords: physical fitness, job performance, fitness programme, lean muscle mass, aerobic capacity

DECLARATION

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LIST OF ABBREVIATIONS

1. Maximum oxygen uptake (VO_{2max})
2. Self contained breathing apparatus (SCBA)
3. Personal protective equipment (PPE)
4. Body mass index (BMI)
5. Cardiovascular disease (CVD)
6. One-repetition maximum (1-RM)
7. Lean muscle mass (LMM)
8. Multistage shuttle test (MSST)
9. Fat percentage (fat %)

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Introduction

Minimal research has been performed on the relationship between occupational performance and functional occupational physical fitness measures. The tasks performed by fire-fighters are strenuous and require protective clothing to be worn together with a self-contained breathing apparatus. This adds an additional mass of approximately 25kg that they need to carry while performing job specific tasks. This makes fire-fighting one of the most physically strenuous and perilous occupations (Findley *et al.* 2002). Hilyers et al. (1999) reports that fire-fighting ranks among the five leading international occupations which possesses the highest prevalence of injuries and illness (Hilyer *et al.* 1999).

Mier and Gibson (2004) reported that the primary contributing factors of injury, illness and mortality among firefighters are occupational stress, burden of carrying the heavy protective clothing and sudden volatile fluctuations of heart rate response (Mier and Gibson 2004). Call outs are sudden and can range in severity and duration. Heart rates have been found to range from 84–100% of an individual's maximum, and these heart rates correspond to a 63–97% of estimated maximum oxygen uptake (VO_2max) (Perroni *et al.* 2009). Despite the requirement for a high level of fitness for optimal performance, it is estimated that approximately 80% of fire departments neglect the maintenance of basic health and fitness programmes of their fire-fighters (Peterson *et al.* 2008).

Peterson et al. (2006) reported that many fire stations fail to prioritize optimal fitness conditioning as their primary goal to attain peak occupational performance. This results in the following maladies, musculoskeletal injuries and overexertion with on-duty fire-fighters (Peterson *et al.* 2008; Sell 2010). Work-related injuries in the fire service have been projected to be four times that of the private industry (Peterson *et al.* 2008). Work-related disorders include muscular sprains and strains, and other disorders related to tendons, ligaments and joints (Sell 2010). The common sites for injuries include the back and the shoulders. Forty one percent of all injuries occurred while extinguishing or neutralizing the fire (Security 2008). The fire-fighters are also exposed to awkward positions, tight spaces and vibrating equipment which all increase the risk of injury (Sell 2010).

Fire-fighters' fitness models have developed from the general health and fitness models created for healthy sedentary populations (Peterson *et al.* 2008). Unfortunately these models fulfil the needs for the general public and are not specifically detailed for fire-fighting specific health and fitness. Investigations have been carried out to determine the functional physiological functioning for safe and successful employment for professional fire-fighters. These investigations have expressed the need for superior health and fitness, compared to the general public, to manage the typical job-specific tasks of a fire-fighter. The fitness requirements recommended include significant cardiovascular fitness and a substantial level of muscular development (muscular endurance, absolute strength, relative strength, and power) (Peterson *et al.* 2008).

Testing the fitness levels of fire-fighters using standard fitness tests is well practiced and may offer good insight into the fire-fighters' fitness levels, but this fitness needs to translate into job performance. Testing fire-fighters' job performances through job-simulated tasks will offer more information on occupation-related fitness (Rhea *et al.* 2004).

Previous research has investigated the relationship between fire suppression and physical fitness; however these studies employed a small battery of tests and primarily focused on cardiovascular and muscular endurance (2.4km run, push-ups and sit-ups) i.e. standard fitness tests (Rhea *et al.* 2004). To the best of the researcher's knowledge, Rhea, Alvar and Gray (2004) are the only group that has examined the relationship between physical fitness and job performance using a large range of physical fitness tests (Rhea *et al.* 2004). This research was performed on 20 professional fire-fighters from the Phoenix Fire Department, Phoenix, Arizona, USA. This study found numerous significant correlations between physical fitness and job performance tasks but found no correlation between cardiovascular fitness and overall fitness (Rhea *et al.* 2004). The reason for the insignificant finding was the allowance for full recovery between job performance tasks (Rhea *et al.* 2004).

Limited research has been published examining the association between physical fitness measures and functional occupational performance of fire-fighters (Rhea *et al.* 2004). Currently there is no South African specific testing battery to examine fire-fighting performance and South Africa has no normative data for fire-fighters for fitness levels or job performance tasks. Specifically, the eThekwini Fire Department, who will provide subjects for the present study, use normative data from American and Australian fire-fighters. This normative data is not culturally specific nor does it take into account different fire suppression methods used in different countries.

Therefore, the aim of the study will be to assess the correlation between fitness tests (cardiovascular endurance and muscular development) and job-specific tasks in professional South African male fire-fighters. This would fill a gap in research but more importantly help to improve the effectiveness of fire-fighters in South Africa.

1. Chapter 1: Literature Review

1.1 Introduction

The tasks performed by fire-fighters are strenuous and require protective clothing to be worn together with a self-contained breathing apparatus (SCBA). This adds an additional mass of up to approximately 35kg that fire-fighters need to carry while performing job tasks. These factors play a role in making fire-fighting one of the most physically strenuous and perilous occupations (Williford *et al.* 1999; Findley *et al.* 2002; Coca *et al.* 2010; Tierney *et al.* 2010). Per 1000 fires, approximately 23-25 fire-fighters are injured (Smith 2011). The stress of this occupation, all the protective gear worn and the unexpected change from rest to high intensity work is a large contributor to an increased mortality from cardiovascular disease in fire-fighters (Mier and Gibson 2004). This lead to the International Association of Fire-fighters (IAFF) recommending fire-fighters participate in fitness training to ensure that fire-fighters are able to meet the physical requirements of fire fighting (Findley *et al.* 2002). This review will examine the literature on the physiological characteristics and physical features required to be a successful fire-fighter.

1.2 Aerobic capacity

Many tasks have to be performed by fire-fighters when suppressing a fire or responding to an emergency. These tasks include climbing ladders, carrying and operating heavy equipment, carrying victims and crawling through debris and tight spaces. Fire-fighters are required to work near to or at maximum capacity for unpredictable amounts of time in extreme environmental conditions (Mier and Gibson 2004; Tierney *et al.* 2010). The high demands and stress placed on fire-fighters requires them to be sufficiently fit to optimize job performance and minimize injuries (Mier and Gibson 2004). It is of utmost importance that the fire-fighters have well-conditioned cardio-respiratory systems (Perroni *et al.* 2009; Tierney *et al.* 2010).

The stress of the environment that fire-fighters have to work in and the personal protective equipment (PPE) they wear has been shown to increase energy expenditure by 25%, and decrease endurance performance by 22% and 75% for low and high intensity work, respectively (Mier and Gibson 2004; Perroni *et al.* 2009). Therefore, cardiovascular fitness is vital with cardiovascular disease or events contributing to almost half of deaths in fire-fighters (Mier and Gibson 2004; Rosenstock and Olsen 2007).

Earlier studies suggested a lower limit of maximum oxygen uptake (VO_{2max}) of 41 to 45 ml/kg/min was required to meet the demands of fire-fighting (Lemon and Hermiston 1977; Sothmann *et al.*

1992; Bilzon *et al.* 2001; Mier and Gibson 2004). However, there was variation in the protocols used to assess VO_{2max} in these studies and therefore it is difficult to draw comparisons. Some studies used maximal tests (Perroni *et al.* 2009; Tierney *et al.* 2010), others submaximal protocols (Misner *et al.* 1989; Swank *et al.* 2000; Peate *et al.* 2002; Angerer *et al.* 2008; Donovan *et al.* 2009), while some used questionnaires (Poston *et al.* 2011) and others did not indicate how the VO_{2max} was measured (Barr *et al.* 2010). The Gerkin Treadmill protocol is a popular submaximal protocol and is endorsed by the Labor Management Wellness/Fitness Initiative (Mier and Gibson 2004), for testing the aerobic fitness of fire-fighters. The test does not require expensive equipment and is relatively safe to perform (Donovan *et al.* 2009; Tierney *et al.* 2010). However, it has been shown to over predict VO_{2max}. Research demonstrated that over prediction occurred in 93% of participants and in 33% of these the over prediction was greater than 25% (Mier and Gibson 2004).

von Heimburg et al. (2006) divided the firefighters into a fast (less than 6 min) or slow (more than 6.5 min) group depending on their time to complete the 6 patient rescues. They found the faster group to have an 18% higher peak O_2 uptake. The peak VO_{2max} for the patient rescue was 3.7 l/min, but with the need to complete the entire task (ascends 6 floors of stairs and rescue 6 patients) in 7 min this would require a minimum of 4.0 l/min. This lead the authors to suggest a minimum absolute VO_{2max} for fire-fighters should be 4.0 l/min (von Heimburg *et al.* 2006). Sothman et al. (1990) had a group of 32 fire-fighters participate in a protocol involving fire-fighting tasks and seven fire-fighters from the group voluntarily quit due to excessive fatigue. These seven fire-fighters had VO_{2max} levels below 35 ml/kg/min. From this study another important finding was the increase in time to complete simulated tasks with the advancement of age even with subjects matched for VO_{2max} (Sothmann *et al.* 1990). In another study that included 150 fire-fighters divided into five groups according to age, Saupe et al. (1991) showed a decrease in aerobic power with age. Aerobic power decreased from 47.7 ml/kg/min in the 20-25 year-old group to 37.9 ml/kg/min in the 30-35 year-old group and from 37.9 ml/kg/min in the 30-35 year-old group to 31.5 ml/kg/min in the 40-45 year-old group (Saupe *et al.* 1991). These finding have major implications for fire-fighters of advancing age as the demands of fire-fighting remain constant regardless of age.

Call outs to fires and emergencies are sudden and can range in severity and duration. Heart rates were shown to range from 84–100% of an individual's maximum, with these heart rates corresponding to 63–97% of estimated VO_{2max} (Williams-Bell *et al.* 2008; Perroni *et al.* 2009). Similarly, Michaelides et al. (2011) showed that fire-fighting tasks had an energy expenditure corresponding to 50-85% of a fire-fighter's VO_{2max} (Michaelides *et al.* 2011). This shows that fire-fighters work close to their maximum capacity and require a high level of cardiorespiratory fitness.

Despite the requirement for a high level of fitness for optimal performance, it is estimated that approximately 80% of fire departments overlook the maintenance of basic health and fitness programmes of their fire-fighters (Peterson *et al.* 2008). One study, surprisingly demonstrated that fire-fighters had the same level of fitness as the average person (Lemon and Hermiston 1977).

1.3 Anaerobic fitness

To date, research has focused primarily on the aerobic aspects of fire-fighting, measured during simulated or actual work (Findley *et al.* 2002). However, high correlations have been shown between anaerobic capacity and tasks such as the stair climb, victim rescue and hose operation (Findley *et al.* 2002; Williams-Bell *et al.* 2008).

Fire-fighting activities were shown to require a contribution of ~40% of total energy expenditure to be from the anaerobic system (Lemon and Hermiston 1977). However, a study by Perroni et al. (2009) suggested a lower contribution, with 14% attributed to the anaerobic system (9% alactic and 5% lactic). Studies have reported blood lactate levels up to 13.1 mmol/l during simulated fire-fighting activities (von Heimburg *et al.* 2006; Holmer and Gavhed 2007; Barr *et al.* 2010). These high levels of lactate may have caused fatigue but the effect was dependent on the level of fitness of the fire-fighter (Bilzon *et al.* 2001). In individuals with a greater aerobic capacity, the anaerobic threshold typically occurs at a high percentage of maximum aerobic capacity (Barr *et al.* 2010). Because of the anaerobic threshold occurring at higher percentages of VO_{2max}, a higher percentage of energy is developed from the aerobic system during higher intensity work. This also allows for a shorter recovery from high-intensity work (Lemon and Hermiston 1977; Bilzon *et al.* 2001).

Strong correlations between anaerobic capacity and fire-fighters' work performance have been found. Fire-fighters who performed better at the 400m sprint performed significantly better at the stair climb, victim rescue, ventilation, equipment hoist, hose operating (Lemon and Hermiston 1977; Misner *et al.* 1989; Gledhill and Davis 1992; Rhea *et al.* 2004). Female fire-fighters anaerobic capacity was measured by use of the Wingate Anaerobic Test. The authors reported that female fire-fighters achieved an anaerobic capacity similar to that of the general female population and that females may not have the skeletal muscle capacity to perform the high intensity work needed for fire-fighting (Findley *et al.* 2002).

1.4 Muscular Development

Fire-fighters rated tasks such as carrying ladders and using manual/hydraulic equipment to be, in terms of muscular strength and endurance the most demanding and frequently completed tasks (Lusa *et al.* 1994). A substantial level of muscular development (muscular endurance, absolute strength, relative strength, and power) may improve job performance but may also act to prevent injury (Peterson *et al.* 2008; Smith 2011). The relationship between muscular strength and fire-fighting activities is well documented. Many studies has used the isometric hand grip strength test as a marker for upper body strength (Williford *et al.* 1999; Bilzon *et al.* 2001; Rhea *et al.* 2004) as it correlates highly with upper body strength and lean muscle mass (Leyk *et al.* 2007). A strong correlation was reported between fire-fighting tasks such as equipment hoist, forcible entry, chopping tasks and victim rescue and hand-grip strength (Williford *et al.* 1999; Bilzon *et al.* 2001; Rhea *et al.* 2004). Rhea et al. (2004) discussed that tasks such as the hose pull, victim drag and equipment hoist all require muscular strength (Rhea *et al.* 2004). von Heimburg et al. (2006) found that larger, and heavier fire-fighters with a high absolute VO_{2max} were shown to complete tasks quicker, used more aerobic power, and also used less air from their SCBA (von Heimburg *et al.* 2006).

Naclerio et al. (2009) demonstrated that muscular endurance is influenced by maximal strength. They also suggested that to increase muscular endurance, muscular strength should increase to a point where the specific load lifted repeatedly is less than 40% of the maximum load (Naclerio *et al.* 2009). As strength is directed related to muscle cross-sectional area, it could be said that those with a low muscle mass may perform poorly on the fire-fighting activities (Barr *et al.* 2010).

Sothmann et al. (2004) used a battery of field tests that included a hose drag, arm lift, and arm endurance exercise. When combined, these tests could identify 82% of successful and 72% of unsuccessful performers (Sothmann *et al.* 2004). Henderson et al. (2007) noted that a high level of strength was a good predictor of fire-fighting activities (Henderson *et al.* 2007). Sothmann et al. (2004) and Henderson et al. (2007) both supported the use of simple field tests of strength in predicting fire-fighting performance (Sothmann *et al.* 2004; Henderson *et al.* 2007). To date, no studies have examined isokinetic strength in fire-fighters. Such assessments could provide useful information and insight relating to possible muscle imbalances and altered muscle force coupling in fire-fighters that could be use for planning conditioning, injury prevention and rehabilitation programmes.

1.5 Body Composition

A number of studies have found the prevalence of overweight and obesity, according to body mass index (BMI), is high in career fire-fighters, ranging from 73% - 88%, and 76%-87% in volunteer fire-fighters (Poston *et al.* 2011). Poston et al. (2011) showed that fire-fighters with a BMI above 30.2 were twice as likely (98%) to experience an adverse employment event than those with a BMI below 27.2.

Research suggested that fire-fighters with a high BMI will have an impaired vascular function and an increased risk for cardiovascular disease (CVD) (Soteriades *et al.* 2008; Poston *et al.* 2011). Cardiovascular disease is the leading cause of fire-fighter line-of-duty deaths, accounting for approximately 45% of all on-duty deaths (Poston *et al.* 2011). According to Tierney et al. (2010), fire-fighters with low aerobic fitness have a 90% greater risk of myocardial infarction compared to those who are aerobically fit. The leading cause of death among career and volunteer fire-fighters is coronary heart disease which has a prevalence of 39% and 50% respectively (Tierney *et al.* 2010). These proportion are greater than those of other occupations such as for police (22%), other emergency medical services (11%), and all other on-duty occupations (15%) (Poston *et al.* 2011).

A limitation of the use of BMI for obesity classification is that it may overestimate obesity in muscular people (Poston et al. 2011). However, misclassifying of muscular fire-fighters as obese occurred very infrequently, and when assessed through body fat percentage the prevalence of obesity was even higher (Poston *et al.* 2011).

Not only does being overweight increase and individual's risk of CVD, but excess fat is associated with low fitness (Poston *et al.* 2011). Tsismenakis et al. (2009) showed that no lean fire-fighter failed to reached a 12 METs exercise tolerance level, while 7% of overweight and 42% of obese fire-fighters failed (Tsismenakis *et al.* 2009). In addition, numerous studies demonstrated physical fitness to be associated with an increase in job performance (Hilyer *et al.* 1999; Williford *et al.* 1999; Rhea *et al.* 2004; Del Sal *et al.* 2009; Naclerio *et al.* 2009; Michaelides *et al.* 2011).

Williford et al. (1999) reported correlations between body fat percentage and fat-free mass with simulated fire-fighting tasks such as stair climbing, forcible entry, hose hoist, victim rescue and advancing a hose. The strongest correlation was with the stair climb. Individuals with the higher fat percentage performed poorly compared to the leaner fire-fighters. This suggested that excess body fat acts as extra mass that needs to be carried, that impacts negatively on fire-fighting performance (Williford *et al.* 1999). Michaelides et al. (2011) demonstrated that abdominal strength, step test, push-ups, resting heart rate, and body fat percentage all contributed to the prediction of the fire-fighters' ability test (Michaelides *et al.* 2011).

1.6 Fire-fighting demands

Fire-fighting tasks place a large demand on the fire-fighter. Tasks include the ladder and stair climb, victim rescue and equipment usage and removal. These tasks could result in near to maximal heart rates and a need for both the anaerobic and aerobic systems to contribute. In addition to the demands of the tasks the external stressors (environment and protective clothing) make these tasks increasingly strenuous (Bilzon *et al.* 2001). The greatest energy expenditure for fire-fighters is found when fire-fighters have to carry heavy equipment as well as their own body mass against gravity (e.g. climbing stairs) while wearing full fire-fighting protective clothing as well as the SCBA. This was reported in civilian (Lemon and Hermiston 1977; O'Connell *et al.* 1986; Gledhill and Davis 1992; von Heimburg *et al.* 2006; Holmer and Gavhed 2007), industrial (Weafer 1999), and navy (Bilzon *et al.* 2001) fire-fighters.

Holmer and Gahved (2007) measured the metabolic cost of simulated work tasks. These tasks were; walking/running on flat ground, climbing three flights of stairs and descending four flights of stairs, with each task being performed twice. The average completion time for the entire simulated work task was 22 min, with an average VO_{2max} of 2.75 l/min (33.9 ml/kg/min). The highest VO_{2max} was observed while completing the stair climb with a VO_{2max} of 3.55 l/min (43.8 ml/kg/min). The authors showed that those fire-fighters who had a high aerobic fitness were able to complete the simulated tasks in the shortest time (Holmer and Gavhed 2007). In support of this finding, O'Connell et al. (1986) reporting a minimum VO_{2max} of 3.7 l/min (39 ml/kg/min) was required to complete a five minute stair climbing treadmill test at a rate of 60 steps/min in full protective clothing (O'Connell *et al.* 1986).

von Heimburg et al. (2006) reported that the energy cost of a simulated victim rescue was high. Each fire-fighter had to climb six floors (vertical assent of 20.5 m) carrying a 10 m hose, axe and a flashlight. Once at the top of the stairs, the fire-fighters had to rescue six victims by dragging them to a rescue mat (covering a total of 162 m). Mean VO_2 max, heart rate and blood lactate was measured once at the top of the stairs and again on completion of the victim rescue. Mean VO_2 max, heart rate and blood lactate at the top of the stairs were 2.8 l/min (44 ml/kg/min, 88% maximum), 167±13 beats/min (83% maximum) and 6.8mmol/l respectively. The completion heart rate and blood lactate means were 182 beats/min and 13mmol/l, with the highest VO_2 max value being after the victim rescue of 3.7 l/min (von Heimburg *et al.* 2006).

Lemon and Hermiston (1977) examined energy expenditure in fire-fighters dressed in full PPE. The fire-fighters performed tasks such as an aerial ladder climb, victim rescue, hose drag and ladder raise. These tasks were performed separately to investigate the individual intensities. All four tasks were shown to be very similar with the fire-fighters working at around 70% VO_{2max}, 10 METS and using around 12 Kcal/min. They also showed that fire-fighters with a VO_{2max} greater than 40 ml/kg/min were able to complete tasks with a greater reliance on the aerobic system compared to those with a VO_{2max} of less than 40 ml/kg/min, who were reliant on the anaerobic process to complete the tasks (Lemon and Hermiston 1977).

Fire-fighters encounter many different situations and these situations all require very specific tasks to be performed. The industrial environment is very different to that of the civilian fire-fighting. Weafer (1999) examined the demands on fire-fighters during a petrochemical fire. Tasks such as raising a ladder, forcible entry, and overhauling a ceiling were very uncommon but tasks such as pulling a trailer (210 kg) over gravel, opening and closing valves, climbing 10 m vertical ladders, running out hoses and hoisting hoses up 10 m high structures were very common. The mean VO_2max and heart rate for all the tasks were 40.14 ml/kg/min and 171 beats/min respectively. The trailer had the greatest metabolic usage of 46.38 ml/kg/min and 174 beats/min (Weafer 1999).

Fire-fighters on board a ship are required to perform tasks specific to the environment they encounter. The quantification of metabolic demands of tasks specific to Royal Navy fire-fighters on board a ship revealed a VO_2 max of 52.6 ml/kg/min (males) and 43 ml/kg/min (females). The tasks completed were the boundary cooling, extinguisher carry, drum carry, hose run and ladder climb. The fire-fighters had to perform each task for a 4-minute period. The lowest heart rate response of 77% of maximum was elicited by the boundary cooling and the maximum of 88% was elicited by the drum carry task. The boundary cooling also elicited the lower metabolic demand of 44% VO_2 max for males and 55% VO_2 max for females, while the drum carry was the most demanding requiring 82% and 78% VO_2 max in males and females respectively (Bilzon *et al.* 2001).

The above data indicates that fire-fighting is an occupation that requires a high level of physical preparedness. Fire-fighters require not only strength but anaerobic, aerobic power and muscular endurance to be able to complete the tasks needed to save lives. The allocation of specific fitness programmes and time for training should be made to maintain and improve fitness and should be evidence-based (Barr *et al.* 2010).

1.7 Actual emergencies

Very few studies have examined the response to live fires as it is impractical and could place the fire-fighter in dangers. A few studies have monitored heart rate during work (Sothmann *et al.* 1992; Bos *et al.* 2004) but they provided no information on the environmental conditions. In an actual emergency call out it was found that fire-fighters heart rates ranged between 84-100% of the individuals maximum and this corresponded to a 63-97% of estimated VO_2max (Sothmann *et al.* 1992).

1.8 Conclusion

For a fire-fighter to meet the needs of the job as a fire-fighter, they must possess a high level of aerobic power, anaerobic power, muscular strength and endurance, as well as a lean body composition. The literature suggests that fire-fighters struggle to maintain a level of fitness that meets the needs of the job. Fire stations and management need to ensure that they provide conditioning programmes that prepare fire-fighters for the specific fitness demands of the job. With CVD being a major concern for fire-fighters it is essential that all members of the fire fighting staff undergo health screening regularly.

2. CHAPTER 2: SCIENTIFIC PAPER PUBLICATION

Association between physical fitness and job performance in fire-fighters

2.1 Abstract

The purpose of the study was to examine the relationship between a selected battery of physical fitness measures and job performance in fire-fighters. Forty-eight experienced, professional firefighters (30.15 ± 7.24 yrs) participated in fitness and job performance testing sessions each spaced a week apart. Analysis was performed using Pearson moment correlation coefficients and multiple linear regression with alpha set at $p \leq .05$. Significant correlations ($p \leq .01$) were found between a job performance task (Revised Grinder) and the following: lean muscle mass (r = -.69), overall fitness (r = -.62), height (r = -.62), strength endurance: deadlift (r = -.54), bent-over row (r = -.51), bench press (r = -.51), shoulder press (r = -.46); maximal strength: hand grip strength (r = -.57), bench press (r = -.51), anaerobic capacity: 400m (r = .50), and aerobic capacity: multistage shuttle run (r = -.46). Multiple linear regression determined that lean muscle mass and aerobic capacity account for 82% of the variation in the job performance task. **Conclusion** It is apparent that fire fighting stresses virtually all aspects of physical fitness. The fire department's incumbent exercise specialist is advised to engage fire-fighting in tasks and physical activities that will enhance performance.

Keywords: physical fitness, job performance, fitness programme, lean muscle mass, aerobic capacity

2.2 Introduction

The primary task of a fire-fighter is to save lives and remain safe. Fire-fighters are the first to arrive at emergencies and have to act fast, work fast and make quick decisions. The actions and decisions could make a difference in the survival and safety of not only the victim but also the entire fire-fighting team. The tasks performed by fire-fighters require personal protective equipment (PPE) to be worn together with a self-contained breathing apparatus (SCBA). This additional mass of approximately 25kg, together with the thermal strain, makes fire-fighting one of the most physically strenuous occupations (Findley *et al.* 2002). The stress of this occupation, all the protective gear worn and the unexpected change from rest to high intensity work is a large contributor to an increased mortality from cardiovascular disease in fire-fighters (Mier and Gibson 2004). Annually, fire-fighting ranks in the top five occupations in job-related injuries and illnesses (Hilyer *et al.* 1999).

Call-outs are sudden and can range in severity and duration with heart rates (HR) ranging from 84–100% of an individual's maximum HR, with these HR's corresponding to a 63–97% of estimated maximum oxygen uptake (VO_2max) (Perroni *et al.* 2009). Many studies have shown that oxygen expenditure for fire-fighters in various simulated tasks range from 23 to 43.5 ml/kg/min (Smith *et al.* 2001; Peate *et al.* 2002; Holmer and Gavhed 2007; Williams-Bell *et al.* 2008; Donovan *et al.* 2009). The extra mass of the PPE and SCBA increases energy expenditure by 25% and decreases low and high intensity running by to 22% and 75% respectively (Perroni *et al.* 2009). This shows that fire-fighters work close to their maximum capacity and require a high level of physical fitness. Despite this, it is estimated that approximately 80% of fire departments overlook the maintenance of basic health and fitness programmes of their fire-fighters (Peterson *et al.* 2008).

With many departments not prioritizing the health and fitness of their fire-fighters, musculoskeletal injuries, overexertion and substandard physical fitness are a major cause of injuries with on-duty fire-fighters (Peterson *et al.* 2008; Sell 2010). Work-related injuries in the fire service have been projected to be four times that of the private industry (Peterson *et al.* 2008). Work-related disorders include muscular sprains and strains, and other disorders related to tendons, ligaments and joints (Sell 2010). The common sites for injuries include the back and the shoulders with 41% percent of all injuries occurring while extinguishing or neutralizing a fire (Security 2008). Fire-fighters are also exposed to awkward positions, tight spaces and vibrating equipment which all increases the risk of injury (Sell 2010).

Health and fitness models have been developed from the general population norms to provide practical and general recommendations for fire-fighters. Unfortunately these models fulfil the needs for the general public and are not specific or fitting for fire-fighting specific health and fitness (Peterson *et al.* 2008). Many investigations have been carried out to determine the physiological functioning of professional fire-fighters (Holmer and Gavhed 2007; Williams-Bell *et al.* 2008; Del Sal *et al.* 2009; Perroni *et al.* 2009; Williams-Bell *et al.* 2010). These investigations have expressed the need for superior health and fitness to manage the typical job-specific tasks of a fire-fighter. The fitness requirements recommended include significant cardiovascular fitness and a substantial level of muscular development (muscular endurance, absolute strength, relative strength, and power) (Holmer and Gavhed 2007; Peterson *et al.* 2008; Williams-Bell *et al.* 2008; Del Sal *et al.* 2009; Perroni *et al.* 2009; Williams-Bell *et al.* 2010).

Testing the fitness levels of fire-fighters using standard fitness tests is important and offers insight into the fire-fighters' fitness levels, but this fitness needs to translate into job performance. Testing fire-fighters' job performances through job-simulated tasks will offer more information on occupation-related fitness (Rhea *et al.* 2004). Previous research has investigated the relationship between fire suppression and physical fitness; however these studies employed a small battery of tests and primarily focused on cardiovascular and muscular endurance (2.4 km run, push-ups and sit-ups) (Rhea *et al.* 2004). To the best of the authors' knowledge, Rhea, Alvar and Gray (2004) are the only group that has examined the relationship between physical fitness and job performance using a large range of physical fitness tests. This research was performed on 20 professional fire-fighters from the Phoenix Fire Department (Phoenix, Arizona, USA). This study found numerous significant correlations between physical fitness and job performance tasks but found no correlation between cardiovascular fitness and job performance (Rhea, *et al.*, 2004).

Limited research has been published examining the association between physical fitness measures and job performance in fire-fighters (Rhea *et al.* 2004). Currently there is no South African specific testing battery to examine fire-fighting performance. Therefore, the aim of the study was to assess the relationship between fitness tests (cardiovascular, anaerobic endurance and muscular development) and job-specific tasks in professional South African fire-fighters. This would fill a gap in research but more importantly help to improve the effectiveness of fire-fighters in South Africa.

2.3 Methodology

The sample consisted of 48 experienced, professional firefighters (males n =43, females n =5). The fire-fighters were recruited from the three primary fire stations in the eThekwini Municipality. The fire-fighting platoons from each of the fire stations participated in the study. These platoons consist of full-time, professional fire-fighters that represent the general population of South African fire-fighters. The study was approved by the Biomedical Research Ethics Committee of the University of KwaZulu-Natal.

The inclusion criterion was that the fire-fighter had to be a current professional firefighter and have two or more years of experience. Participants were excluded if they had any injury or medical condition that prevented full participation or if they had less than two years experience as a professional firefighter.

Before the commencement of the study, a survey was performed on 186 firefighters to identify which fire-fighting tasks are performed most frequently and the critical impact of each task. The survey required the firefighters to rate the importance of 32 job specific tasks that firefighters perform. The results were then used to help guide the development of the job specific tasks that were used in the study. All tasks developed were assessed by senior management with the fire department. Table 1 provides a list of the top 14 tasks and the name of the simulated task that was developed to test the job performance in the firefighters.

2.3.1 Testing session 1

Testing occurred in the Human Performance Laboratory and Gymnasium in the Discipline of Sport Science at the University of KwaZulu-Natal. All participants received an explanation of the procedures and possible risks associated with exercise testing, following which they provided informed consent. The participants then completed a pre-participation screening questionnaire and medical history questionnaire.

2.3.2 Anthropometry

Body mass and stature were measured using a calibrated electric scale and stadiometer (Nagata, model BW-1122H, Taiwan). Participants removed their shoes and wore shorts and a t-shirt. Stature was measured barefoot and to the closest millimeter. Skinfold thickness measurements were taken using a Harpenden caliper. Seven sites were measured: chest, tricep, mid-auxiliary, subscapula, supra-iliac, thigh and calf. The Durnin and Womersley equation was used to estimate body fat percentage and lean muscle mass (Durnin and Womersley, 1974). All measurements were performed before exercise testing.

Table 2.1. Survey results and simulated tasks developed to test job performance

Rank	Survey answers	Simulated Tasks
1	Extend dry hose line from fire apparatus to fire occupancy	Hose Pull
2	Enter through a door using force	Tire and Sledgehammer Test
3	Crawl through smoke filled structures pulling charged hose	Attic crawl
4	Remove ladder from fire apparatus, carry and place at structure	Ladder Raise
5	Climb ladder carrying tools	-
6	Remove equipment from fire apparatus and carry to scene	-
7	Climb stairs carrying high rise pack	Stair Climb
8	Hook up to hydrant	-
9	Pull ceiling to check for fire extension	-
10	Drag dry supply line from apparatus to hydrant	Hose pull
11	Search for victim in fire occupancy with limited visibility	Attic crawl
12	Remove victim or injured partner from fire scene	Victim drag
13	Extricate victim from vehicle	Static jaws-of-life hold
14	Raise or lower equipment from windows	Equipment hoist

2.3.3 Physical fitness parameters

Physical fitness parameters were assessed using the testing order and protocols recommendations by the National Strength and Conditioning Association (Harman 2008; Harman and Garhammer 2008). A minimum rest period of five minutes was allowed before the start of each physical fitness test and a three-five minute rest between attempts. Although all participants had over two years training experience, the participants were allowed one set of each exercise for familiarization purposes.

2.3.3.1 Maximal Muscular Strength

A one-repetition maximum (1-RM) test was performed for the following: bench press, deadlift and leg press. A hand grip strength test for both hands was determined using a hand dynamometer (Jamar, J00105, USA).

2.3.3.2 Local Muscular Strength Endurance

Participants completed as many repetitions as possible for the given exercise and prescribed mass. The resistance for each exercise was set to represent the mass of the various pieces of equipment used in fighting fires. All major pieces of equipment was weighed and tasks such as the bent-over row, bicep curl and seated shoulder press used weights similar to that of the equipment used. For example a pair of jaws-of-life weighed approximately 15kg and a rolled hose approximately 15kg. The exercises assessed were the bench press with a mass of 45-kg, leg press with 50% of 1-RM, bent-over row with a 20-kg dumbbell (dominant hand only), dumbbell preacher bicep curls with 14-kg dumbbells and seated shoulder press with 12-kg dumbbells. Hand grip endurance was measured with a hand grip dynamometer. The participants squeezed sufficiently to exert a force over 25-kg. The participants held this force for as long as possible. The abdominal curl test was then performed. The participants had to complete as many repetitions as possible within two minutes.

2.3.3.3 Anaerobic power/endurance

The participants had to run around a 400 m track as quickly as possible while being timed with a stopwatch.

2.3.3.4 Cardiovascular endurance

The multistage shuttle test was used to measure cardiovascular fitness. The protocol set by Leger and Lambert (1982) required the participants to run back-and-forth (‘‘shuttles’’) between 2 rows of cones placed 20 m apart from one another. The starting speed of the test was 8.5 km/hr, and increased by 0.5 km /hr every minute. An audible ‘‘beep’’ sounded each time the subject was expected to reach a cone to complete a shuttle. Each stage was approximately 1 minute in length and the number of shuttles per stage was adjusted according to the speed of the shuttles. Participants received verbal encouragement throughout the duration of the test. When a participant failed to complete two consecutive shuttles in the allotted time (beeps), the test was terminated for that subject. Estimated VO_2 max was determined from a printed table by using the number of shuttles completed (Leger and Lambert 1982).

2.3.4 Job performance tests

The job performance tasks were completed seven to ten days following the completion of the physical fitness measures. All job performance tasks were performed either at the eThekwini Central or Pinetown Fire and Emergency Services Station, Durban, South Africa.

Five separate job performance tasks followed by a combination of the tasks (the Revised Grinder Test) were tested. The time (seconds) to complete the Revised Grinder Test was recorded and used as an overall job performance score. The participants were each randomly assigned an order to complete the individual job tasks. A minimum of five minutes rest was allowed between the individual job tasks and a minimum of ten minutes rest before the start of the Revised Grinder Test.

The participants completed all tasks in their specified fire-fighting turnout clothing (9.6kg), including boots, pants, coat, gloves and helmet.

The individual job performance tasks were all scored by the time to complete the task and included:

Hose pull: A 63 mm, uncharged (dry) rolled fire hose (13.5 kg) was placed on the fire-fighters shoulder. The participants sprinted a distance of 60 m with the hose held on one shoulder.

Stair climb: A 15-kg gym plate was held in each hand while ascending and descending one flight (15 steps, 15.5 cm height per step) of stairs for five repetitions. Participants were not permitted to skip stairs on the ascent or descent.

Simulated victim drag: An 80 kg tyre was dragged on a cement surface 30 m. Participants were permitted to pull the tyre facing forward or backward. A rope (60 cm) connected the tire to a T-bar.

Simulated ladder raise: A ladder was raised 15 m against a tower. A rope was placed through a pulley 12 m high and returned to the ground. A 15 kg weight was attached to one end of the rope. The participants raised the 15 kg weight up 12 m and returned it back to the ground. This was completed for two repetitions. The participants had to use a hand-over-hand method to raise and lower the weight; no sliding of the rope was permitted.

Equipment hoist: From a 10 m tower participants had to raise and lower a 20 kg weight attached to a 15 m rope for two repetitions. The participants were not permitted to slide the rope on the decent and used a hand-over-hand method for raising and lowering the weight.

The Revised Grinder test: This test was a modification of The Grinder Test (Peterson *et al.* 2008) and the CPAT (Williams-Bell *et al.* 2008). The tasks used were judged to be representative of the tasks performed according to the survey complete, the fire department administrative staff and previous research (Rhea *et al.* 2004; Peterson *et al.* 2008; Williams-Bell *et al.* 2008). The revised grinder incorporated the job performance tasks but also allowed for a correlation between overall fitness and cardiovascular fitness to be. The test consisted of seven separate tasks all performed in sequence as fast as possible and timed for an overall performance. All participants ran the same order of tasks for the Revised Grinder. The order was as follows:

Simulated ladder raise: A ladder was raised 15 m against a tower. A rope was placed through a pulley 12 m high and returned to the ground. A 15-kg weight was attached to one end of the rope. The participants raised the 15-kg weight up 12 m and returned it back to the ground. This was completed for two repetitions. The participants had to use a hand-over-hand method to raise and lower the weight, no sliding of the rope was allowed.

Hose pull: A 63 mm, uncharged (dry) rolled fire hose (13.5 kg) was placed on the fire-fighters shoulder. The participants sprinted a distance of 60 m with the hose held on one shoulder.

Static Jaws-of-Life hold: A pair of jaws-of-life was held with both hands waist height for one minute.

Tyre and sledge hammer test: Participants had to move a 105-kg truck tyre (71 cm diameters) a distance of 30 cm with the use of a 4.54-kg sledge hammer. The tyre was placed on a plywood table 92 cm high (Pelot *et al.* 1999).

Stair climb: A 15-kg gym plate was held in each hand while ascending and descending one flight (15 steps, 15.5 cm height per step) of stairs for five repetitions. Participants were not permitted to skip stairs on the ascent or descent.

Attic Crawl: The participants had to crawl (hands and knees) a distance of 15 m through a 1 m x 1 m built structure. The structure had two 90° corners and two obstacles placed on the floor.

Simulated victim drag: An 80-kg tyre was dragged on a cement surface 30 m. Participants were permitted to pull the tyre facing forward or backward. A rope (60 cm) connected the tyre to a T-bar.

2.4 Statistics

The data were analyzed with a 1-sample nonparametric test (Kolmogorov-Smirnov test) to determine whether the data distribution was normal. Descriptive statistics (mean ± SD) were calculated and the significance of associations between physical fitness measures and the job performance measures were determined using Pearson product moment correlation coefficients and multiple linear regression (Stepwise method). For the multiple linear regression, the Revised Grinder test was set as the dependent variable and the independent variables included the descriptive and physical fitness measures. All the independent variables were correlated with each other and checked for collinearity. Once the variables with interrelationships (correlations ≥ .70) were removed, the five variables with the highest correlations were selected for the multiple linear regression. Significance was set a $p \leq .05$. All statistics were run using the IBM SPSS version 19 (IBM, USA).

2.5 Results

Table 2 presents the demographic, physical fitness and job performance descriptive statistics for the 48 South African fire-fighters. Their mean age of 30.15 ± 7.24 years, lean muscle mass (LMM) of 66.88 ± 9.16 kg and body fat percentage of 12.6 ± 6.11 % were lower than that reported for other fire-fighters (Williford *et al.* 1999; Rhea *et al.* 2004).

Table 2.2 Descriptive Statistics

	MEAN (SD)
Age (Years)	30.15 (7.24)
Body Mass (Kg)	76.96 (12.48)
Height (m)	1.71 (.08)
Fat % (%)	12.60 (6.11)
BMI (Kg/m^2)	26.27 (3.34)
LMM (Kg)	66.88 (9.16)
Bench Press Strength (Kg)	98.33 (23.57)
Deadlift Strength (Kg)	141.77 (22.94)
Leg press Strength (Kg)	337.48 (81.23)
Hand Grip Strength Avg (Kg)	55.65 (8.75)
Bench Press Endurance (reps)	29.48 (29.48)
Bent-over row Endurance (reps)	36.21 (36.21)
Bicep Curl Endurance (reps)	30.79 (14.67)
Shoulder Press Endurance (reps)	32.40 (14.02)
Leg Press Endurance (reps)	33.77 (12.36)
Hand Grip Endurance Avg (reps)	71.94 (21.36)
2min Abdominal Curl (reps)	82.46 (17.22)
400m Sprint (s)	83.60 (15.03)
Multistage Shuttle Test (level. stage)	7.33 (2.05)
Predicted VO2max (ml/kg/min)	37.56 (6.99)
Revised Grinder (s)	407.75 (107.60)

Table 3 presents the correlations between the descriptive and physical fitness and the job performance measures. Significant correlations ($p \leq .01$) were found between the Revised Grinder and the following: lean muscle mass ($r = -.69$), overall fitness ($r = -.62$), height ($r = -.62$), hand grip strength ($r = -.57$), deadlift ($r = -.54$), bent-over row ($r = -.51$), bench press strength ($r = -.51$), bench press endurance ($r = -.51$), 400m ($r = .50$), bleep ($r = -.46$) and shoulder press ($r = -.46$). Significant correlations were also identified for each of the individual job performance tasks (Table 3). The multiple linear regression produced 2 models (Table 4). Model 1 used LMM to predict the job performance time ($r = .69$, $r^2 = .48$, SE = 78.64). Model 2 used LMM and the multistage shuttle test (MSST) ($r = .82$, $r^2 = .67$, SE = 63.09). The best model for predicting job performance time was model 2. Both models were highly significant with $p < .001$.

Table 2.3. Pearson Product Moment Correlations

		Hose Pull	Stair Climb	Victim Drag	Equipment Hoist	Ladder Raise	Revised Grinder
Age		.209	.178	.066	.010	-.042	.209
	N	48	48	47	48	47	48
Body Mass		-.170	-.003	-.486**	-.330*	-.278	-.422**
	N	48	48	47	48	47	48
Height		-.237	-.243	-.568**	-.436**	-.390**	-.620**
	N	48	48	47	48	47	48
Fat %		.360*	.471**	.202	.252	.178	.370**
	N	48	48	47	48	47	48
BMI		-.049	.161	-.221	-.113	-.094	-.092
	N	48	48	47	48	47	48
LMM		-.374**	-.247	-.675**	-.505**	-.405**	-.691**
	N	48	48	47	48	47	48
Bench Press Strength		-.411**	-.353*	-.560**	-.523**	-.413**	-.511**
	N	48	48	47	48	47	48
Deadlift		-.397**	-.181	-.547**	-.555**	-.358*	-.543**
	N	48	48	47	48	47	48
Leg press Strength		-.261	-.248	-.435**	-.438**	-.262	-.395**
	N	48	48	47	48	47	48
Hand Grip Strength Avg		-.299*	-.228	-.521**	-.503**	-.428**	-.573**
	N	48	48	47	48	47	48
Bench Press Endurance		-.428**	-.367*	-.550**	-.536**	-.502**	-.508**
	N	48	48	47	48	47	48
Bent-over Row		-.467**	-.331*	-.508**	-.426**	-.354*	-.535**
	N	48	48	47	48	47	48
Bicep Curl		-.553**	.060	-.447**	-.340*	-.465**	-.431**
	N	48	48	47	48	47	48
Shoulder Press		-.422**	-.425**	-.466**	-.492**	-.408**	-.461**
	N	48	48	47	48	47	48
Leg Press Endurance		.032	-.159	.064	-.121	-.223	-.007
	N	48	48	47	48	47	48
Hand Grip Endurance Avg		-.144	-.117	-.388**	-.215	-.257	-.412**
	N	48	48	47	48	47	48
2min Abdominal Curl		.036	-.107	.243	.027	.094	.069
	N	48	48	47	48	47	48
400m Sprint		.555**	.363*	.350*	.358*	.367*	.500**
	N	48	48	47	48	47	48

Multistage Shuttle Test (MSST)		-.368**	-.398**	-.305*	-.215	-.141	-.464**
	N	48	48	47	48	47	48
VO_2 max		-.367*	-.399**	-.306*	-.214	-.139	-.464**
	N	48	48	47	48	47	48
Overall Fitness		-.483**	-.380**	-.607**	-.604**	-.479**	-.629**
	N	48	48	47	48	47	48

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 2.4. Multiple Linear Regression

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.69[a]	.48	.47	78.64
2	.82[b]	.67	.66	63.09

a. Predictors: (Constant), LMM
b. Predictors: (Constant), LMM, MSST

Table 2.5. Multiple Linear Regression Coefficients

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
2	(Constant)	1107.44	74.35	-.69	11.25	.00
	LMM	-7.94	1.01	-.68	-6.48	.00
	MSST	-23.06	4.48	.44	-5.14	.00

2.6 Discussion

The multiple linear regression (Table 4) predicted 2 models that could account for 69% - 82% of the variance in job performance time. Model 2 indicates that LMM and the MSST are the best predictors for the job performance task and accounts for 82% of the variation in job performance time with a SEE of 63.09 seconds. The equation for model 2 follows:

Completion time = 1107.44 – (7.94 * LMM) - (23.06 * MSST)

The negative correlations for LMM and the MSST indicates that as the time to complete the job performance task decreases there was an increase in LMM and aerobic fitness. This model indicates that fire-fighters with a large muscle mass and high aerobic capacity will perform best at the job performance task. This finding is similar to that of previous research (Williford *et al.* 1999), where fat free mass, cardiovascular fitness and muscular strength accounted for 53% of the variance in job performance. The heavy machinery and equipment used as well as the added mass of the personal protective equipment worn, makes fire-fighting one of the most strenuous occupations in the world (Findley *et al.* 2002). Without significant muscular strength fire-fighters would be unable to perform optimally and this is indicated in the regression model. The heat fire-fighters must endure, together with the continuous nature of fire-fighting tasks, increases the stress on the cardiovascular system. An increase in cardiovascular fitness facilitates the recovery from high intensity bouts and increases the efficiency of heat dissipation (Rhea *et al.* 2004). The finding that fire-fighters in actual emergency reach an energy expenditure of 63–97% of estimated maximum oxygen uptake reinforces the need for a high cardiovascular fitness (Perroni *et al.* 2009).

As fire-fighting is one of the most physically demanding occupations in the world the findings are useful for the identification of potential fire-fighters. Performing tests that measure LMM and cardiovascular fitness (multistage shuttle test) in large groups of new recruits each year would be cost effective and relatively simple. The regression equation allows for the prediction of job performance based on the two fitness parameters discussed above. However, further tests, such as the 400m sprint, upper body strength and endurance, which were all correlated with the job performance tasks, could also be included in a more comprehensive test for new recruits as well as routine testing of fire-fighters.

The size of the correlations found demonstrates the high demands placed on muscular strength, muscular endurance, anaerobic power and aerobic capacity during job performance. Previous studies have utilized fitness test such as the broad jump, push-up, pull-up, sit-up and vertical jump (Findley *et al.* 1995; Williford *et al.* 1999). Whereas in the current study, similar to that of Rhea, *et* *al.* (2004), a more comprehensive range of fitness tests was employed. The hose pull was significantly correlated with body composition (fat% and LMM), upper and lower body strength (bench press, deadlift, hand grip), upper body muscular endurance (bench press, bent-over row, bicep curl and shoulder press), anaerobic power (400m sprint), and cardiovascular endurance (multistage shuttle test). The stair climb was correlated with fat %, upper body strength and endurance, as well as anaerobic power, and cardiovascular endurance. Variables that were significantly correlated to the victim drag were body mass, height, LMM, whole body strength, upper body endurance, anaerobic power and cardiovascular endurance. For the equipment hoist body mass, height, LMM, whole body strength, upper body endurance, and anaerobic power were of significance. The ladder raise was correlated to height, LMM, upper body strength and endurance and anaerobic power. Overall job performance (Revised Grinder) was significantly correlated with body composition, full body strength, upper body endurance, anaerobic power and cardiovascular endurance, with the strongest correlations being with LMM ($r = -.69$) and overall fitness ($r = -.63$). Unlike Rhea *et al.* (2004), a significant correlation was found between cardiovascular endurance and overall job performance (Table 4). The reason for the conflicting finding may be because Rhea *et al.* (2004) allowed for a full recovery between the job performance tasks. A test that is often used in testing is the abdominal curl endurance test. The present study, similarly to previous research (Rhea *et al.* 2004) found no correlations between abdominal endurance and any job performance tasks. Although the abdominal curl test may be an effective tool for assessing abdominal muscle endurance, core development and the risk of back injury, this test is ineffective at evaluating fire fighting job performance (Rhea *et al.* 2004). In summary, it is apparent that each job task stresses a number of physical fitness components. Therefore, an enhancement in the physical fitness components related to a specific job performance task would be expected to improve the performance in that task. The correlations between the physical fitness tests and the separate job performance tasks are useful for strength and conditioning staff. These correlations can assist in the development of conditioning programmers and help individuals address any specific weakness in their job performance. Trainers should not ignore the exercises that correlate poorly with any job specific task, such as the abdominal curl and leg press endurance.

Anecdotally, fitness testing of fire-fighters at fire stations in South Africa is limited and not comprehensive. The result is that the fitness levels of the majority of South African fire-fighters across South Africa is currently unknown, with the possibility that many fire-fighters may be neglecting important areas of their fitness which are linked with their job performance. The results from the present study have demonstrated that fitness testing should involve testing areas that are associated with predicting job performance.

2.7 Conclusion

Fire fighting is a vigorous and demanding occupation. Physical fitness is of major importance and the allocation of gym and fitness programmes to fire-fighters is imperative. Previous training has primarily focused on muscular strength and cardiovascular endurance (Rhea *et al.* 2004). The research shows that if muscular endurance and anaerobic endurance are neglected it could have negative effects on job performance and the wellbeing of the fire-fighters. Ensuring fire-fighters are physically prepared in all fitness areas will assist in decreasing the risk of injury and illness. Exercise specialists should focus on setting fitness programmes that are individualized and that focus on all the fitness aspects required of a fire-fighter while increasing LMM and decreasing body fat. The job performance tasks can be used not only in training but also in testing for new recruits. The Revised Grinder test provides a good indication of overall fitness, strength and endurance.

3. CONCLUSION

It is apparent that fire-fighters stress all aspects of physical fitness. Tasks that simulate fire-fighting job tasks are an important aspect to add into the fire-fighting training. The fire department's incumbent exercise specialist is advised to engage fire-fighters in tasks and physical activities that will enhance their job performance.

Simulated tasks such as the Revised Grinder can be used to test, assess and train potential new recruits as well as full-time professional fire-fighters.

The use of testing LMM and the MSST as predicted by the multiple linear regression could help in assessing potential new recruits as these tests are easy and quick to complete and can also be done with large numbers.

Further research needs to be completed on real-fire emergencies. Research into actual fire emergencies would give a much clearer view on the actual demands and also how fitness could affect job performance.

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APPENDIX

Appendix I

Information Sheet

Dear ____

You have been invited by Masters Candidate Carl Schmidt and Associate Professor Andrew McKune from the Discipline of Sport Science, University of KwaZulu-Natal, to participate in a study examining the association between physical fitness levels and job performance in fire-fighters.

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. Please recognize that your participation is completely voluntary. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the Aim of the Project?

This project is being undertaken as part of the requirements for a postgraduate Master's degree in Sport Science. The aim is to evaluate the correlation between job performance and specific fitness such as aerobic capacity, anaerobic capacity, strength and strength endurance.

What Type of Participants are Needed?

This study requires participants who have 2 years or more experience as an active professional fire-fighter and are between the ages of 22-40. Participants will be excluded if they currently carry an injury or have a medical condition preventing them from full participation or obtain an injury during the testing.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to fill out forms and be involved in a testing protocol. Written informed consent will be obtained from all participants, and the study will be approved by the University of KwaZulu-Natal Research Ethics Committee.

We will test participants in the Human Performance Laboratory situated in the Discipline of Sport Science at the University of KwaZulu-Natal Westville and at the eThekwini Fire and Emergency

Services Department. Participant will be required to attend 2 full days of testing.

The following tests and evaluations will be performed:

Day 1- Physical Fitness

Day one will take place at the University of KwaZulu-Natal, Sport Science. This day will be used to complete medical history forms (including orthopaedic injuries), informed consent forms, to complete an ECG stress test, and to complete the physical fitness tests.

Fitness tests: (all tests have a minimum of 10 minutes rest between each other)

1. Anthropometry tests: These include height, mass, body mass index (BMI), and fat percentage (7 site skin-fold test). BMI is calculated by one's mass divided by height squared. Fat percentage is done by measuring the fat content beneath the skin. At the site of measurement the skin is softly pinched between the tester's finger and thumb. The skin-fold caliper is placed over the fold of skin next to the finger and thumb, and measures the thickness of the fold. This is done at all 7 sites (chest, midaxillary, triceps, subscapular, abdomen, suprailiac, and thigh).
2. Strength test: The bench press, Deadlift, squat and hand grip strength will be tested. After warming up the tester will decide on a starting mass. Only one successful lift in needed to progress to a heavier mass. With each successful lift the mass of the exercise is increased until a maximum weight is found. The hand grip test will be done with a hand dynamometer. This devise is held in the hand and is squeezed as hard as possible for about 5 seconds. Both arms are tested.
3. Local muscular endurance: To test endurance a light weight is selected and as many repetitions as possible must be completed. The exercises being used are the bench press (45kg), squat (60kg), bent-over row (20kg dumbbell), dumbbell biceps curl (14kg) and seated shoulder press (12kg dumbbell). The weight for each exercise is predetermined. These weights are based on general firefighting equipment.

A hand grip endurance test will also be done. A hand grip dynamometer is used again. A force of over 25kg must be place on the dynamometer and held for as long as possible. The test end when the force drops below 25kg.

An abdominal endurance test will also be completed. As many abdominal crunches as possible must be completed. A metronome will be set at a cadence of $30b.min^{-1}$. You will be stopped once you fall more than 1 beat behind the metronome or fail to complete a full repetition.

4. Anaerobic capacity: A 400m sprint will be run and timed on an outdoor track.

5. Aerobic capacity: The multistage beep test will be used. The beep test is set out over 20m. The subject run according to the beeps played through the CD player. Initially the test starts off very slow and plenty time is given to run the 20m. Once the 20m is covered you must wait for the next beep before setting off for the next shuttle. Each beep (shuttle) gets progressively quicker and you must continue until fatigue causes you to fail. The test is stopped if you don't make the full 20m for 2 consecutive beeps (shuttles).

Day 2: Job Performance tests: (all tests have a minimum of 10 minutes rest between each other) Day 2 testing will take place at the eThekwini Central fire station, Durban.

1. Hose pull: An uncharged (dry) fire hose will be pulled as quickly as possible to a length of 65m. The hose will be laid out in 5m segments to simulate a withdrawal from a fire engine. A maximum of 2m may be wrapped around the fire-fighter's waist/shoulders, with both hands holding the nozzle. Timing will begin on the command and stopped once the hose end crosses the start line.

2. Stair climb: 2 rolled hoses will be carried while ascending and descending 5 flights of stairs. Fire-fighters will be required to touch each step on ascent and descent.

3. Simulated victim drag: An 80kg tire will be dragged 30m. The fire-fighters will be required to run backwards and the test will start with the mannequin flat on its back.

4. Equipment walk: The participant will have to remove two pieces of equipment from a truck (jaws-of-life and a pump), walk/run the equipment out 30m to a wall and place the equipment on the floor. The participant will then have to pick up the jaws-of-life and touch 5 markings on a wall (all placed at different heights). Once complete the participant must pick up the pump and walk/run both pieces of equipment back to the truck and place them back on the truck.

5. Equipment hoist: A 15kg weight will be attached to a rope and hoisted a length of 12.1m. The test will start on command and the test will end when 2 full repetitions are completed.

6. The Revised Grinder: This will include a circuit of 6 tasks performed without a rest in-between each task. The entire test will be timed. The task includes an equipment hoist, hose pull, the tire and sledgehammer test, stair climb, attic crawl and victim drag.

6\. 1. Equipment hoist: A 30kg iron pipe will be attached to a rope and hoisted a length of 12.1m. The test will start on command and the test will end when 2 full repetitions are completed.

6\. 2. Hose pull: A 5cm uncharged fire hose will be pulled a length of 65.6m. The hose will be laid out in 5m segments to simulate withdrawal from a fire engine. Fire-fighters may wrap a maximum of 2m of hose around their waist or shoulders with both hands holding the nozzle. Time continues from the equipment hoist.

6. 3. Equipment walk: The participant will have to remove two pieces of equipment from a truck (jaws-of-life and a pump), walk/run the equipment out 30m to a wall and place the equipment on the floor. The participant will then have to pick up the jaws-of-life and touch 5 marking on a wall (all placed at different heights). Once complete the participant must pick up the pump and walk/run both pieces of equipment back to the truck and place them back on the truck.

6. 4. Tire and sledgehammer test: This test simulates hammering and axe chopping. Using a 4.54kg sledge hammer, the fire-fighters must drive a truck tire weighed down to 105kg (71cm diameter) 30cm. The tire will be placed on a table with a plywood table top. Time continues from hose pull.

6.4 . Stair climb: 2 rolled hoses will be carried while ascending and descending 5 flights of stairs. Fire-fighters will be required to touch each step on ascent and descent. Time continues from the tire and sledgehammer test.

6. 6. Attic Crawl: This test simulates a fire attic crawl. Fire-fighters must crawl on hands and knees through a 15m long, 1 x 1 meter crawl space. The course will have 2 right angle corners. No lighting assistance will be given. Time continues from the stair climb.

6. 6. Simulated civilian carry/drag: Fire-fighters will drag an 80kg mannequin backwards as quick as possible over 20m. The time is stopped at the completion of this task.

Possible risks and discomforts:

Resting Measures: Measurement of ECG, height and mass will produce no physical discomfort. Skin-folds (testing body fat percentage) may produce slight pressure for a few seconds when the skin is pinched to get a measurement but will disappear immediately after releasing the skin.

Fitness and job performance test: The physical tests completed may cause discomfort due the fatigue but ample rest and recovery will be given. There is a 6 in 10000 chance of a cardiac event such as heart attack occurring during the fitness and job performance tests, but this risk is lower in healthy individuals and every effort will be made to minimize the risks of such an event. You may also experience some muscle soreness or fatigue as a result of the exercise you will have to perform. The fatigue experienced will not be greater than what a fire-fighter would experience during routine training or fighting a fire.

Potential benefits of this study:

South Africa has no normative data or testing battery for the fire department to use for training or recruitment of new fire-fighters. This study will provide them with this information which will help in these processes. This study will also provide the fire departments with data to work from to create accurate and meaningful fitness programmes which would not only help the fire-fighters but decrease injuries and help the fire-fighters perform to a higher standard.

Can Participants Change their Mind and Withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What Data or Information will be collected and What Use will be made of it?

Fitness levels and job task performance results will be collected. This information will be correlated against each other to see what exercises best correlate with fire fighting specific tasks. Results of this project may be published but any data included will in no way be linked to any specific participant.

You are most welcome to request a copy of the results of the project should you wish.

The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

What do participants have to avoid prior to testing?

Participant will be asked to please not train the day before the testing.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact either:-

Carl Schmidt or Professor Andrew McKune

Department of Sport Science | Department of Sport Science

Tel No: 083 535 9490 | University Tel No: 031 260 7394

This project has been reviewed and approved by the Faculty Ethics Committee

Of the UNIVERSITY OF KWAZULU-NATAL

Appendix II

Informed Consent Sheet

Dear ____

You have been invited by Masters Candidate Carl Schmidt and Associate Professor Andrew McKune from the Discipline of Sport Science, University of KwaZulu-Natal, to participate in a study examining the association between physical fitness levels and job performance in fire-fighters.

The researcher will recruit 100 participants aged 22 to 40 years.

PLAN AND PROCEDURES:

Data collection:

You will be required to attend 2 consecutive days of testing. Day 1 will include the filling out of all forms and will consist of anthropometry and physical fitness test. Day 2 will consist of job performance tasks.

(a) Contact Details: I agree to give basic information and contact details about myself to the researcher including my name, age (date of birth), address and phone number.

(b) Medical History/Physical Activity Form: I agree to give information about my medical history and physical activity. The purpose of completing this form is to ensure that I meet the medical requirements to be included in this study and that the researcher obtains information to declare me "apparently healthy" for inclusion as a participant.

(c) Baseline Data Collection: I agree to have my height, mass, and skin-fold measurements taken.

RISKS AND DISCOMFORTS

Baseline Measurements: Measurement of height and mass will produce no physical discomfort. Skin-folds (testing body fat %) may produce slight pressure for a few seconds when the skin is held to get a measurement but will disappear immediately after releasing the skin.

The Physical Tests: The physical tests completed may cause discomfort due the fatigue but ample rest and recovery will be given. There is a 6 in 10000 chance of a cardiac event such as heart attack occurring during the fitness and job performance tests but this risk is lower in healthy individuals and every effort will be made to minimize the risks of such an event. You may also experience some muscle soreness or fatigue as a result of the exercise you will have to perform. The fatigue experienced will not be greater than what a fire-fighter would experience during routine training or fighting a fire.

POTENTIAL BENEFITS

South Africa has no normative data or testing battery for the fire department to use for training or recruitment of new fire-fighters. This study will provide them with this information which will help in these processes. This study will also provide the fire departments with data to work from to create accurate and meaningful fitness programmes which would not only help the fire-fighters but decrease injuries and help the fire-fighters perform to a higher standard.

TERMINATION OF PARTICIPATION

I understand that if the screening and data collection procedures provide evidence that the tests or activities cannot be safely performed , or if I have a pre-existing condition which will not allow me to participate in the study, I will be informed at that time and will not be included in the study. I understand that the investigator will explain the reason for the exclusion to me.

COSTS/COMPENSTAION

The policy of the University of KwaZulu-Natal does not provide for compensation or medical treatment to participants who are injured as a result of this research study. However, every effort will be made to make the tests and activities as safe as possible, with little risk of injury.

JOB SECURITY

Participation is this study will not jeopardize job position or job security.

CONFIDENTIALITY

All data and information collected in this study will be maintained in complete confidence and privacy will be protected. I will not be identified in any report or presentation by name as a result of this study.

You have been informed about the study in detail by Carl Schmidt.

You may contact the investigators in this study, Master’s candidate Carl Schmidt (0835359490), Associate Prof. Andrew McKune (031-260-7985), any time if you have questions about the research or if you are injured as a result of the research.

You may contact the **Biomedical Research Ethics Office** on **031-260 4769 or 260 1074** if you have questions about your rights as a research participant.

Your participation in this research is voluntary, and you will not be penalized or lose benefits if you refuse to participate or decide to stop at any time.

If you agree to participate, you will be given a signed copy of this document and the participant information sheet which is a written summary of the research.

The research study, including the above information, has been described to me orally. I understand what my involvement in the study means and I voluntarily agree to participate. I have been given an opportunity to ask any questions that I might have about participation in the study.

Signature of Participant **Date**

Signature of Witness **Date**

This project has been reviewed and approved by the Faculty Ethics Committee of the University Of KwaZulu-Natal

Appendix III

Medical History Questionnaire

Name__________________________Sex_______Age______Date of Birth__________________
Sport(s)__________________Phone_______________E-mail Address______________________
In case of emergency, contact
Name_______________Relationship_________Phone(H)______________(W)______________

Explain "Yes" answers on second page	Y	N
1. Has a doctor even denied or restricted your participation in sports for any reason?	☐	☐
2. Do you have an ongoing medical condition (like diabetes or asthma)?	☐	☐
3. Are you currently taking any prescription or nonprescription (over-the-counter) medicines or pills?	☐	☐
4. Do you have allergies to medicines, pollens, foods, or stinging insects?	☐	☐
5. Have you ever passed out or nearly passed out DURING exercise?	☐	☐
6. Have you ever passed out or nearly passed out AFTER exercise?	☐	☐
7. Have you ever had discomfort, pain, or pressure in your chest during exercise?	☐	☐
8. Does your heart race or skip beats during exercise?	☐	☐
9. Has a doctor ever told you that you have (check all that applies)? ☐ High Blood Pressure ☐ High Cholesterol ☐ A heart murmur ☐ A heart infection	☐	☐
10. Has a doctor ever ordered a test for your heart? (for example, ECG, echocardiogram)	☐	☐
11. Has anyone in your family died for no apparent reason?	☐	☐
12. Does anyone in your family have a heart problem?	☐	☐
13. Has any family member or relative died of heart problems or of sudden death before age 50?	☐	☐
14. Does anyone in your family have Marfan's syndrome?	☐	☐
15. Have you ever spent the night in a hospital?	☐	☐
16. Have you ever had surgery?	☐	☐
17. Have you ever used an inhaler or taken asthma medicine?	☐	☐
18. Were you born without or are you missing a kidney, an eye, a testicle, or any other organ?	☐	☐
19. Have you had infectious mononucleosis (mono) within the last month?	☐	☐
20. Do you have any rashes, pressure sores, or other skin problems?	☐	☐
21. Have you had a herpes skin infection?	☐	☐
22. Have you ever had a head injury or concussion?	☐	☐
23. Have you been hit in the head or been confused or lost your memory?	☐	☐
24. Have you ever had a seizure?	☐	☐
25. Do you have headaches with exercise?	☐	☐
26. Have you ever had numbness, tingling, or weakness in your arms or legs after being hit or falling?	☐	☐
27. Have you ever been unable to move your arms or legs after being hit or falling?	☐	☐
28. When exercising in the heat do you have severe muscle cramps or become ill?	☐	☐
29. Has a doctor told you that you or someone in your family has sickle trait or sickle cell disease?	☐	☐
30. Have you had any problems with your eyes or vision?	☐	☐
31. Do you wear glasses or contact lenses?	☐	☐
32. Do you wear protective eyewear, such as goggles or a face shield?	☐	☐
33. Are you happy with your weight?	☐	☐
34. Are you trying to gain or lose weight?	☐	☐
35. Has anyone recommended you change your weight or eating habits?	☐	☐

36. Have you ever had a stress fracture?	☐ ☐	42. Do you limit or carefully control what you eat?	☐ ☐
37. Have you been told that you have or have you had an x-ray for atlantoaxial (neck)?	☐ ☐	43. Do you have any concerns that you would like to discuss with a doctor?	☐ ☐
38. Do you regularly use a brace or assistive device?	☐ ☐	**FEMALES ONLY**	
39. Has a doctor ever told you that you have asthma or allergies?	☐ ☐	44. Have you ever had a menstrual period?	☐ ☐
40. Do you cough, wheeze, or have difficulty breathing during or after exercise?	☐ ☐	45. How old were you when you had your first menstrual period?	_____
41. Is there anyone in your family who has asthma?	☐ ☐	46. How many periods have you had in the last year?	_____

Explain "Yes" answers from previous page here:__________________________________

List all *__previous injuries__* and *__approximate dates.__* Check N/A if not applicable

N/A ☐ Shoulder/Elbow (dislocation, rotator cuff, AC separation):________________ Date:_________
N/A ☐ Arm/Wrist/Hand (fractures):____ Date:_________
N/A ☐ Neck (burners, pinched nerve):______________________________________ Date:_________
N/A ☐ Ribs/Abdomen:____ Date:_________
N/A ☐ Low back pan (herniated disc):______________________________________ Date:_________
N/A ☐ Leg (quadriceps, hamstring strain):___________________________________ Date:_________
N/A ☐ Knee (ligament, meniscus, patella):___________________________________ Date:_________
N/A ☐ Lower leg (shin splints, calf strain):__________________________________ Date:_________
N/A ☐ Ankle/Calf/Foot (sprain, Achilles):___________________________________ Date:_________
N/A ☐ Stress Fractures:____ Date:_________
N/A ☐ Concussions:____ Date:_________

If yes, have you ever been knocked out (unconscious)? Yes: ☐ No: ☐
How many times?___________________________
How long were you unconscious?____
Have you ever lost your memory? Yes: ☐ No: ☐
How many times?___________________________
Did you have problems in the days afterward (confusion, headache, concentration)?
Yes: ☐ No: ☐
How long did it take you to recover?_____________
Are you still having problems? Yes: ☐ No: ☐

Do you have any unhealed or chronic injuries? Yes: ☐ No: ☐
Please list:____

I hereby state that, to the best of my knowledge, my answers to the above questions are complete and correct.

Signature of athlete____ Date___________

Signature of parent/guardian____ Date_____________

Appendix IV

AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire

Assess your health status by marking all *true* statements

History

You have had:

_____ a heart attack
_____ heart surgery
_____ cardiac catheterization
_____ coronary angioplasty (PTCA)
_____ pacemaker/implantable cardiac defibrillator/rhythm disturbance
_____ heart valve disease
_____ heart failure
_____ heart transplantation
_____ congenital heart disease

Symptoms

_____ You experience chest discomfort with exertion
_____ You experience unreasonable breathlessness
_____ You experience dizziness, fainting, or blackouts
_____ You take heart medications.

Other health issues

_____ You have diabetes
_____ You have asthma or other lung disease
_____ You have burning or cramping sensation in your lower legs when walking short distances
_____ You have musculoskeletal problems that limit your physical activity
_____ You have concerns about the safety of exercise
_____ You take prescription medications
_____ You are pregnant

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a ***medically qualified staff.***

Cardiovascular risk factors

_____ You are a man older than 45 years
_____ You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal
_____ You smoke, or quit smoking within the previous 6 months
_____ Your blood pressure is >140/90 mm Hg
_____ You do not know your blood pressure
_____ You take blood pressure medication
_____ Your blood cholesterol level is >200 mg/dL
_____ You do not know your cholesterol level
_____ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister)
_____ You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week)
_____ You are >20 pounds overweight

If you marked two or more of the statements in this section you should consult your physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a ***professionally qualified exercise staff***[a] *to guide your exercise program.*

_____ None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.

[a]Professionally qualified exercise staff refers to appropriately trained individuals who possess academic training, practical and clinical knowledge, skills, and abilities commensurate with the credentials defined in Appendix D.

Appendix V

Data Recording Sheet

Study ID: ____

Body mass: ________ **Height:** ________

Fat %: ________ **BMI:** ________

Sex: ______________

PLEASE CHECK ECG HAS BEEN COMPLETED.

Day 1:

7-site skin-fold

1. Chest ________

2. Midaxillary ________

3. Tricep ________

4. Subscapular ________

5. Abdomen ________

6. Suprailiac ________

7. Thigh ________

Strength Tests

- Bench press ________

- Deadlift ________

- Squat ________

- Hand grip L ________ R ________

<u>Local Muscular Endurance</u>

- Bench Press ________
- Bent-over row ________
- Bicep curl ________
- Shoulder press ________
- Squat ________
- Hand grip L ________ R ________
- Abdominal curl ________

<u>Anaerobic Power</u>

- 400m sprint ________

<u>Cardiovascular Endurance</u>

- beep test ________

<u>Day 2:</u>

Job Performance Tests

- Hose pull ________
- Stair climb ________

- Simulated victim drag ________
- Equipment hoist ________
- Equipment walk ________
- Revised Grinder ________

Appendix VI

eThekwini Fire and Emergency Services Task Analysis Survey

The purpose of this survey, is to identify those task's which are perceived by yourselves to be the most physically demanding tasks, performed by firefighters, which also have the most critical impact to the overall aim, which is preservation of life and property.

The results of this task survey, will then be analyzed and a unique, task specific assessment will be developed from these results, to assess the capability and potential of new candidates to undertake the strenuous and potentially dangerous functions of firefighting.

Your assistance is greatly needed, and it would be appreciated if you could make your judgements based on your experiences, involved in the various activities listed.

Demographic Appraisal:

Region :………………………………..

Platoon:……………………………………………

Age:…………………………

Sex:………………………………………………….

Years of service:…………………..

Rank:…………………………………………………

Please complete the following survey in the following manner:

Physicality scale is measured as such:

1 – not physical (can be maintained for a long duration)

2 – moderately physical

3 – physically demanding (task can be self paced, but sweating and Elevated pulse is experienced)

4 – highly physically demanding (working really hard, hot and sweaty, not a level of work you would be at by choice)

5 – Extremely physically demanding (heart rate close to maximum puffing, not a level that can be maintained for long)

Criticality (measure of importance of task to preservation of life or property) scale is measured as such:

1 – not important at all

2 – moderately important to completion of overall task

3 – could have an impact if not done

4 – has a major impact if not completed.

5 – vital, if not completed death or injury is imminent

Frequency of task:

This basically means how often in a work cycle would you be called upon to do the task. You can simply rate this as an approximation eg. 3x.

Duration of task:

This simply means, that of that specific task, how long would you be engaged in that task at any specific incident.

You can simply rate that in terms of time eg, minutes or hours, or if the task is continuous, or intermittent , if no specified time can be attributed to it.

Ethekwini Fire And Emergency Services Job Task Analysis					
	Task	***physicality scale***	***criticality scale***	***frequency of task***	***estimated duration of task***
1	**wearing full protective clothing including SCBA**				
2	**extend dry hoseline from fire apparatus to fire occupancy**				
3	**enter through a door using force**				
4	**crawl through smoke filled structures pulling charged hose**				
5	**remove ladder from fire apparatus, carry and place at structure**				
6	**climb ladder carrying tools**				
7	**remove equipment from fire**				

	apparatus and carry to scene				
8	**climb stairs carrying high rise pack**				
9	**hook up to hydrant**				
10	**pull ceiling to check for fire extension**				
11	**drag dry supply line from apparatus to hydrant**				
12	**search for victim in fire occupancy with limited visibility**				
13	**remove victim or injured partner from fire scene**				
14	**extricate victim from vehicle**				
15	**raise or lower equipment from windows**				
16	**carry stretcher or gurney**				
17	**move heavy objects to gain access to fire and free trapped person's**				
18	**extend, hold and support a charged attack line with flowing water**				
19	**start power tools**				
20	**walk along uneven/ narrow surfaces**				
21	**operate at elevated heights**				
22	**pull self up and over an obstacle, into an opening**				
23	**removing debris from a fire scene**				
24	**climb fence or wall in full protective clothing, with full protective equipment**				
25	**remove, throw carry salvage covers to protect equipment**				
26	**climb stairs in full protective clothing carrying firefighter equipment**				

27	**roll up hose and place on apparatus**				
28	**advance charged attack line around obstacles while remaining stationary**				
29	**operate fire extinguishers**				
30	**searching for victims in a structure and carrying forcible entry tools**				
31	**extending the fly section of a ladder**				
32	**handling foam concentrate**				
33	**other - please specify in the space provided below.**				

Of the tasks outlined in the table above, please rate your top 8 most physically demanding tasks, by indicating their corresponding number in the space provided below (eg. 1, 4, 14, 22….)

____

Of the tasks outlined in the table above, please rate your top 8 most critical tasks, to the preservation of life and property, if not completed. Do this by indicating their corresponding number in the space provided below.

____

Thank you for your time and effort, and be informed that your assistance has and will contribute to the success of this project.

Appendix VII

Acceptance letter to the Journal of the Ergonomics Society of South Africa

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

Ergonomics SA – official journal of the Ergonomics Society of South Africa
Tel: (046) 603 8468 • Fax: (046) 603 8934 • e-mail: c.christie@ru.ac.za/j.mcdougall@ru.ac.za

20 April 2012

Carl Schmidt

University of KwaZulu-Natal.

carl.sportsmedicine@gmail.com

Dear Carl

MANUSCRIPT:

"Association between physical fitness and job performance in fire-fighters", (Manuscript 11_j13 Association between physical fitness and)

I am pleased to inform you that your paper will be published in one of our two editions this year.

Yours sincerely

June McDougall

for

Dr Candice Christie

Editor: Ergonomics SA

Appendix VIII

Biomedical Ethical Approval

UNIVERSITY OF
KWAZULU-NATAL

RESEARCH OFFICE
Biomedical Research Ethics Administration
Westville Campus, Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604769 - Fax: 27 31 2604609
Email: BREC@ukzn.ac.za
Website: http://research.ukzn.ac.za/ResearchEthics/BiomedicalResearchEthics.aspx

08 September 2010

Mr. C Schmidt
Discipline of Sport Science
Westville Campus
University of KwaZulu- Natal

Dear Mr Schmidt

PROTOCOL: Association between Physical Fitness and Job performance in Male South African Fire-Fighters. REF: BE114/010

EXPEDITED APPLICATION

A sub-committee of the Biomedical Research Ethics Committee has considered and noted your application dated 14 May 2010.

The study was provisionally approved pending appropriate responses to queries raised. Your responses dated 30 August 2010 to queries raised on 17 August 2010 have been noted by a sub-committee of the Biomedical Research Ethics Committee. The conditions have now been met and the study is given full ethics approval and may begin as from 08 September 2010.

This approval is valid for one year from **08 September 2010.** To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (2004), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at http://research.ukzn.ac.za/ResearchEthics11415.aspx.

BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

The sub-committee's decision will be **RATIFIED** at a full sitting of the Biomedical Research Ethics Committee meeting to be held on **12 October 2010.**

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely

Professor D.R Wassenaar
Chair: Biomedical Research Ethics Committee

Appendix IX

Photographs of Testing

Figure 1. Fire-fighters Kit

Figure 2. Fire Training Tower

Figure 3. Simulated ladder raise

Figure 4. Hose Pull

Figure 5. Stair Climb

Figure 6. Jaws-of-life hold

Figure 7. Tyre and sledge hammer test

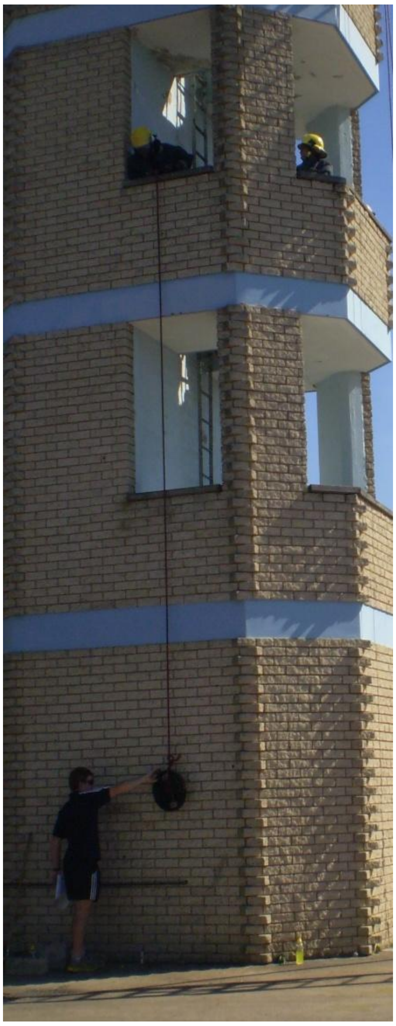

Figure 8. Equipment Hoist